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ABSTRACT

In 1982 and 1983 the Measurement and Evaluation Center of the University of Texas at Austin conducted a set of three studies analyzing student performance in a physics course required for engineering students (Physics 303K) in relation to the students' scores on the College board Mathematics Level 1 and Physics tests and to an introductory physics course (Physics 306). The third of these studies, an investigation of whether the early course, Physics 306, helps overcome weak academic preparation and to determine the score intervals of the Achievement Test in mathematics to be used in placement was repeated in 1991 to update decision foundations. The 1,297 students who met the requirements for inclusion in this study were divided into those who had no previous college physics course before taking Physics 303K and those who has taken Physics 306. The introductory course appeared to be fulfilling its function of providing remediation and improving the chances of success for incoming engineering students. Certain score levels on the mathematics achievement test were recommended for placement decisions, with those scoring below 600 required or strongly advised to take the introductory course, and those scoring above 720 advised to enroll in the higher-level course. Four tables and one figure present study findings. (SLD)

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VALIDITY STUDY OF THE COLLEGE BOARD ACHIEVEMENT TEST IN MATHEMATICS FOR USE IN COURSE PLACEMENT IN ENGINEERING PHYSICS AT UT AUSTIN, 1991

Nancy H. Bené, Nellie S. Cheng,
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In 1982 and 1983, the Measurement and Evaluation Center (MEC) of The University of Texas at Austin conducted a set of three studies analyzing student performance in Physics 303K in relation to the students' scores on two College Board Achievement Tests (Mathematics Level I and Physics) and to an introductory Physics course (Physics 306). Senior faculty members of the Department of Physics had requested the assistance of the MEC because of the high rate of student failure – estimated to be approaching 50% – in Physics 303K, a required course for engineering students during their first semester at the University. The three studies and their results are reported in the Measurement and Evaluation Center Research Bulletin, RB-83-12, December 1983.

The purpose of the third study was to investigate whether Physics 306 helps overcome weak academic preparation in high school mathematics and to determine the score intervals of the College Board Achievement Test in Mathematics Level I to be used in advising engineering students whether to register for Physics 306 prior to enrolling in Physics 303K. MEC staff members concluded that the introductory course, Physics 306, appeared to successfully reduce the effects of weak preparation in mathematics. Seventy-one percent of the students whose Mathematics Level I test scores were in the 200 to 590 range and who enrolled in Physics 306 before taking Physics 303K made satisfactory grades in Physics 303K, compared to 53% of the students who had similar test scores and who enrolled only in Physics 303K. It was therefore inferred that Physics 303K appeared to have saved 18% of the low scoring students from failure.

According to the findings of the third study, the MEC recommended that Mathematics Level I test scores be used for placement of engineering students into Physics 303K or into a sequence of Physics 306 followed by Physics 303K. Students whose test scores ranged between 200 to 590 should be required (or strongly advised) to enroll in Physics 306 before taking Physics 303K; students with scores from 600 to 680 should make their own enrollment decisions regarding Physics 306 and/or Physics 303K; students whose Mathematics Level I test scores were 690 and above should be advised to enroll in Physics 303K.

The MEC staff members presented these results and recommendations to the representatives of the Department of Physics, who in turn informed the Dean of the College of Engineering. The faculty members of the College of Engineering were urged to advise all incoming engineering freshmen who scored below 600 on the Mathematics Level I test to register for Physics 306 before taking Physics 303K. Furthermore, after consultation with the College of Engineering, the Department of Physics decided to offer Physics 306 during the second as well as the first summer term in order to allow students less well prepared in mathematics another opportunity to improve their skills and to increase their chances of succeeding in the engineering curriculum.

From the Fall Semester 1984 to the present time, the official Course Schedules of the University of Texas at Austin have contained the following statement preceding the Department of Physics course listings:

> PHY 306 is a preparatory course for the PHY 303K/303L course sequence. Engineering students who have not taken high school physics, who have a weak mathematical background, or who score less than 600 on the College Board Achievement Test in Mathematics Level I are strongly advised to enroll in this course.

In the spring of 1991, the Department of Physics faculty felt that Physics 306 provides appropriate remediation for the incoming freshman students who are inadequately prepared to take Physics 303K. Of the students who were enrolled in Physics 303K during one of the six semesters from the spring of 1989 to the fall semester 1990, only 20% failed. Even though the recommendation was strongly stated, less than 50% of the students whose scores were below 600 on the Mathematics Level I test chose to enroll in Physics 306. The faculty members considered changing the recommendation so that Physics 306 would become a mandatory requirement for the students with low scores on the Mathematics Level I test. Given the fact that the current advising statement is based on 1982 data analyses, the Department of Physics requested that the MEC redo the third study conducted in 1983, using more recent data.

Method

Subjects

Students who took Physics 303K at UT Austin in one of the six semesters from Spring 1989 through Fall 1990 were designated as subjects if they (a) had enrolled in Physics 303K for the first time; (b) had prior credit for or concurrent enrollment in a laboratory course

(Physics 103M); (c) had prior credit for or concurrent enrollment in Mathematics 408C, 308L, or 308K; (d) had taken the Mathematics Level I test; and (e) had received a letter grade (E - A) in Physics 303K.

Physics 303K is a first semester lecture course in college physics for engineering students, although non-engineering students are also permitted to enroll in the course. It is a survey of physics, primarily covering the laws of motion, heat, and wave phenomena. Its prerequisites include high school study of physics; concurrent enrollment (or prior credit) in its laboratory complement, Physics 103M; and credit for (or concurrent registration in) calculus (Mathematics 408C, 308L or 308K).

The 1,297 students who met the requirements for inclusion in the study were divided into two groups: (1) those who had taken no previous college physics courses prior to enrolling in Physics 303K; and (2) those who had taken the preparatory course, Physics 306, before enrolling in Physics 303K. The first group of students who enrolled immediately in Physics 303K consisted of 1,033 students, while 264 students were members of the group that first took Physics 306 and then enrolled in Physics 303K.

Procedure. Mathematics Level I test scores for the first year engineering students were available from the University data files because that test is required for registration and placement in lower-division mathematics courses at UT Austin.

The statistical investigations conducted in 1991 replicated the aptitude-treatment analyses performed on the 1982 data. Two separate regression analyses were conducted separately for each group of students. The Mathematics Level I test scores were used to predict grades in Physics 303K. Each regression analysis yielded a correlation (validity) coefficient (r) and a regression (prediction) equation. The validity coefficient indicated the correlation or degree of linear relationship between the Mathematics Level I test scores and the grades in 303K. The regression equation enables one to predict the grade in Physics 303K that could be expected of students with a given Mathematics Level I test score.

Once the expected Physics 303K grades were calculated from the Mathematics Level I test scores by use of the two regression equations (one for each group of students), the Johnson-Neyman technique was employed to determine the Mathematics Level I test scores that were

associated with significant differences between the expected grades for the two groups. That is, the Johnson-Neyman technique revealed the score intervals on the Mathematics Level I test that could be used to decide if the engineering students should take Physics 306 before enrolling in Physics 303K.

Results and Discussion

Table 1 presents descriptive statistics for the Mathematics Level I test scores and Physics 303K grades for each of the two groups. The descriptive statistics include the means and standard deviations of the test scores and grades.

The mean of the Mathematics Level I test scores for the Physics 303K group (640.86) was higher than the mean of the test scores for the Physics 306-303K group (536.78). The difference between these means is greater than the difference between the means of the two groups' scores reflected in 1982 data (Physics 306-303K, mean = 544.93; Physics 303K, mean = 622.44). This difference is most likely due to the fact that in 1982 the Mathematics Level I test scores were used only indirectly to advise students about enrolling in Physics 306 or Physics 303K.

Table 1

Descriptive Statistics for Students in the Course Sequence Groups; Scores on the Mathematics Level I Achievement Test and Course Grades in Physics 303K

		Mathematics Level I Test Scores		Physics 303K Grades	
Course Sequence	N	Mean	Standard Deviation	Mean	Standard Deviation
Physics 306-303K	264	536.78	62.71	2.08	1.14
Physics 303K	1033	640.86	65.45	2.46	1.21

The mean Physics 303K grades presented in Table 1 show that the Physics 303K group had a higher mean grade (2.46) than did the Physics 306-303K group (2.08). This pattern is a reversal of the direction of the difference shown by the 1982 data. However, the mean grades for both 1982 groups (Physics 306-303K, mean = 2.16; Physics 306, mean = 2.07) were similar to the level of the present Physics 306-303K group. The higher mean grade of the present Physics 303K group may reflect the higher ability levels as reflected in Mathematics Level I test scores that were higher for the Physics 303K group in the present data than in the 1982 Physics 303K group.

Table 2 presents the validity coefficients and the regression equations that were obtained from the regression analyses. The validity coefficient obtained for the Physics 303K was .42; it indicates that students who received high scores on the Mathematics Level I test tended to perform well in Physics 303K, while students who received low test scores tended to perform poorly in Physics 303K. The validity coefficient of .42 may be considered high enough to justify the use of Mathematics Level I test scores to predict the success of students in Physics 303K.

The validity coefficient of .30 that was obtained for the two-course sequence group is somewhat low; it indicates a moderately weak relationship between the Mathematics Level I test scores prior to taking Physics 306 and the grades students received when they later took Physics 303K. This relationship shows that the Mathematics Level I test score is not as good a predictor of Physics 303K grades if the students take Physics 306 before Physics 303K. The validity coefficient of .30 indicates that students who have low scores on the Mathematics Level I test may be helped by taking Physics 306 prior to taking Physics 303K.

The two regression equations presented in Table 2 were used to calculate the expected grades for students in each of the two course sequence groups. The regression lines shown in Figure 1 graphically depict the expected grades obtained for each of the groups. As can be seen from Figure 1, the regression lines intersect at a Mathematics Level I test score of approximately 720. For students with Mathematics Level I test scores below 720 (the point of intersection), the regression lines indicate that students in the Physics 306-303K group are expected to receive higher Physics 303K grades than students in the Physics 303K group. Conversely, for students with Mathematics Level I test scores above 720, students in the Physics 303K groups are expected to receive higher grades in Physics 303K than students in the Physics 306-303K group.

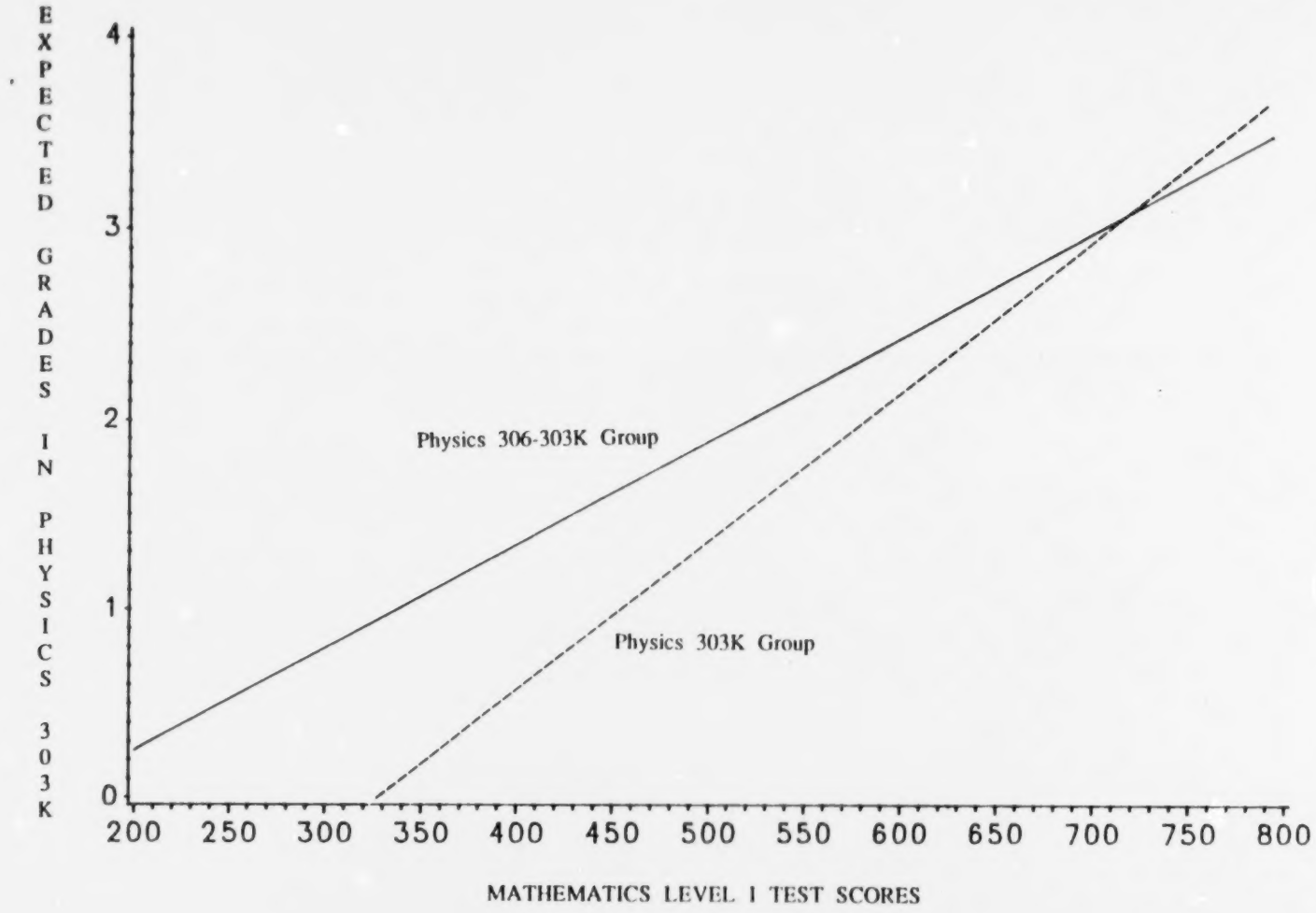

Figure 1. Regression lines for each of the course sequence groups.

Table 2

Results of Regression Analysis for Each of the Course Sequence Groups; Regression Equations and Coefficients of Correlation Between Mathematics Level I Test Scores and Course Grades in Physics 303K

Course Sequence	Regression Equation	Coefficient of Correlation
Physics 306-303K	Expected Grade in PHY 303K = (Math I test score x .0054) - .83383	.30
Physics 303K	Expected Grade in PHY 303K = (Math I test score x .0078) - 2.56093	.42

In order to determine the Mathematics Level I test scores that correspond to statistically significant differences between the expected Physics 303K grades for the two groups, the Johnson-Neyman technique was employed. This analytical technique revealed that the exact point of intersection of the two regression lines was 718.35 and that, for Mathematics Level I test scores lower than 620.88, there was a statistically significant difference between the expected Physics 303K grades for the two groups; that is, students with Mathematics Level I test scores lower than 620.88 can, with reasonable confidence, be expected to perform better in Physics 303K if they take the two-course sequence than if they enroll directly in Physics 303K.

In addition, the analysis revealed that for students with Mathematics Level I test scores higher then 718.35, the differences in the expected grades for the two groups were not statistically significant. Thus, the expected grades for students in the two course sequence groups were significantly different only for Mathematics Level I test scores that were lower than 620.88 – for practical purposes, 620 or lower.

Based on the results of the Johnson-Neyman analysis, the Mathematics Level I test scores were divided into three intervals that could be used to place engineering students into the two-course sequence, Physics 306-303K, or to advise them to directly enroll in Physics 303K. The first interval included Mathematics Level I test scores of 200-620, because the differences

in the expected Physics 303K grades for the two groups were significant for Mathematics Level I test scores lower than 620.88. Students with Mathematics Level I test scores that are in this interval should be advised to take Physics 306 prior to taking Physics 303K because students with mathematics skills at that level who have taken Physics 306 are expected to receive higher grades in Physics 303K than students who have not taken Physics 306.

The second Mathematics Level I test scores interval includes test scores of 630-710 because the intersection point of the two regression lines (718.35) lies between the two scores of 710 and 720. While the students with Mathematics Level I test scores within this interval were expected to receive higher grades in Physics 303K if they had taken the two-course sequence rather than enrolling directly in Physics 303K, such students probably should be permitted to choose whether or not to take Physics 306 prior to Physics 303K because the Johnson-Neyman technique failed to find statistically significant differences between the expected Physics 303K grades for the two groups. For advising purposes, the proximity of a student's Mathematics Level I test score to the lower and upper limits of their score interval should be taken into consideration when advising a student whether or not to take Physics 306 prior to Physics 303K – that is, if a student's Mathematics Level I test score was closer to 630 than 710, he/she should perhaps be advised to take Physics 306 prior to Physics 303K, while a student with a Mathematics Level I test score closer to 710 should perhaps be advised to take Physics 303K as his/her first physics course.

The third Mathematics Level I test score interval includes test scores that range from 720 to 800 because, unlike the other two intervals, students in the Physics 303K group could be expected to receive equal or higher grades in Physics 303K than the students in the Physics 306-303K groups, even though the Johnson-Neyman technique revealed that the differences in the expected grades for this score interval were not statistically significant. Given the direction of the expected grade differences and the fact that the differences were nonsignificant, students whose Mathematics Level I test scores are in this interval should be advised to take Physics 303K as their first physics course.

While the Johnson-Neyman technique yielded information concerning the significant differences between the expected grades for the two groups and the two Mathematics Level I test scores that divided the test scores into three intervals, the technique did not indicate how the students in each score interval for each course sequence actually performed in Physics

303K. Therefore, the students in each course sequence group were assigned to the score intervals recommended by the present analysis in order to inspect the relationship between the recommended score intervals and the students' actual performances (letter grades) in Physics 303K. The grades of the students in each score interval for each course sequence then were collapsed into two categories, Unsatisfactory (grades of E and D) and Satisfactory (grades of C, B, and A) performance in Physics 303K. Table 3 presents the number and percentages of students in the Unsatisfactory and Satisfactory grade classification for each score interval within each course sequence.

The numbers expressed as percentages in the set of columns labeled "Physics 303K Grades" are the percentages of students in a given score interval for a particular course sequence who received unsatisfactory grades and satisfactory grades in Physics 303K, respectively. For example, 26% (N = 61) of the 238 students in the two-course sequence who earned Mathematics Level I test scores lower than or equal to 620 received unsatisfactory grades (E, D) in Physics 303K, while 74% (N = 177) of the students in the two-course sequence who earned Mathematics Level I test scores lower than or equal to 620 received satisfactory grades (C-A) in Physics 303K.

Each number expressed as a percentage in the column labeled "Total" is the percentage of students in the two course sequences whose test scores placed them in one of the three Mathematics Level I test score intervals. For instance, 90% (N = 238) of 264 students in the Physics 306-303K group had received Mathematics Level I test scores lower than or equal to 620.

Tables 3 makes it possible to compare the percentage of students who were in each score interval for each of the course sequence groups; these data enable one to assess the relationship between the score intervals and the students' actual performances in Physics 303K. For the 200-620 score interval, a comparison of the percentages of students who earned satisfactory grades in Physics 303K for each of the course sequence groups reveals that 74% of the students in the two-course sequence group received satisfactory grades in Physics 303K, while 69% of the corresponding students who took only Physics 303K received satisfactory grades.

Table 3

Relationship Between Mathematics Level I Test Score Intervals and Actual Physics 303K Grades for Each of the Two Course Sequence Groups, Physics 306-303K and Physics 303K

Course Sequence	Score Interval	Physics 303K Grades D-F	Physics 303K Grades C-A	Total
Physics 306-303K	720-800	0 0%	2 100%	2 1%
	630-710	2 8%	22 92%	24 9%
	200-620	61 26%	177 74%	238 90%
Physics 303K	720-800	4 3%	136 97%	140 14%
	630-710	74 15%	422 85%	496 48%
	200-620	124 31%	273 69%	397 38%

For the 630-710 score interval on the Mathematics Level I test, a higher percentage of the students in the Physics 306-303K group (92%) received satisfactory grades than the corresponding students in the Physics 303K group (85%). The difference between these two percentages reflects the higher performance of students in the two-course sequence than that of students who did not take the introductory course.

For the highest Mathematics Level I test score interval (720-800), nearly optimum percentages of the students in the 303K group (97%) and the two-course sequence group (100%) received satisfactory grades in Physics 303K. Any comparison of these percentages should be made with caution because only two students in the 720-800 interval elected to take the introductory course, Physics 306.

In general, the findings of the percentage analyses of the actual grades reveals the same conclusions that were drawn from the results of the Johnson-Neyman analysis – that is,

engineering students with Mathematics Level I test scores lower than or equal to 620 should be required (or strongly advised) to take Physics 306 prior to enrollment in the required Physics 303K course; engineering students with Mathematics Level I test scores in the 630- 710 score interval should be allowed to select whichever course sequence they believe would better serve their needs; engineering students with Mathematics Level I test scores higher than 710 should be advised to enroll in Physics 303K as their first physics course.

Recommendations

The introductory course (Physics 306) appears to be fulfilling its function of providing remediation and improving the chances of success for incoming engineering students who are inadequately prepared to take Physics 303K. One indication of its success is given by the correlation coefficients in Table 2. The relationship between Mathematics Level I test scores and Physics 303K grades is lower for the two-course sequence group ($r = .30$) than for the Physics 303K group (.42). The difference between these correlations indicates that the introductory course (Physics 306) appears to reduce the effects of weak preparation in mathematics. A second indication of its effect on Physics 303K performance is to be found in Table 3, which shows that higher percentages of students in each of the three Mathematics Level I test score intervals earned satisfactory grades when they took Physics 306 before enrolling in Physics 303K.

On the basis of the results from the present study, MEC staff members recommend that scores on the Mathematics Level I test be used for placement of engineering students into Physics 306 or Physics 303K and that the following set of scores be used for placement decisions.

Test Scores	Placement
200-620	Student to be required (or strongly advised) to enroll in Physics 306 before enrolling in Physics 303K.
630-710	Student to be advised to make his/her own enrollment decision.
720-800	Student to be advised to enroll in Physics 303K.

However, because a score of 610 on the Mathematics Level I test is the minimum score required to earn credit by examination in Mathematics 305G with a grade of B, MEC staff members modified the first two recommended score intervals to 200-600 and 610-710.

Percentages nearly identical to those shown in Table 3 were obtained in an MEC re-analysis of the data, which used score ranges of 200-600, 610-710, and 720-800. (See Table 4.) Based on this data, MEC staff members recommend the following set of score intervals be used for placement of engineering students into Physics 306 or Physics 303K.

Test Scores	Placement
200-600	Student to be required (or strongly advised) to enroll in Physics 306 before enrolling in Physics 303K.
610-710	Student to be advised to make his/her own enrollment decision.
720-800	Student to be advised to enroll in Physics 303K.

Table 4

Relationship Between Mathematics Level I Test Score Intervals and Actual Physics 303K Grades for Each of the Two Course Sequences: Re-Analysis Using Modified Score Ranges

Course Sequence	Score Interval	Physics 303K Grades D-E	Physics 303K Grades C-A	Total
Physics 306-303K	720-800	0 0%	2 100%	2 1%
	610-710	2 6%	32 94%	34 13%
	200-600	61 27%	167 73%	228 86%
Physics 303K	720-800	4 3%	136 97%	140 14%
	610-710	101 17%	502 83%	603 58%
	200-600	97 33%	193 67%	290 28%